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The RAND Corporation

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Dr. Harry Goode
Bendix Aviation Corporation
Ann Arbor, Michigan

Dear Harry:

By now you should have had ample opportunity to digest the rewrite of my last letter to you; I assume you mailed the extra copies to the other committee men and to Bud Wienberg.

Unfortunately, the task of commenting, correcting, amending and adding to your draft report has turned out to be a rather lengthy job. Because I take this work and the 117-L project seriously, I cannot do otherwise; I hope that as you consider the trade-offs between a timely report and one with more content, you vote for the latter. These are my apologies for the time delay.

You will recall that several of my RAND colleagues attended our Washington meeting. Because of their interest and competence, I have asked them to read and comment on your draft report. Their comments are included in this letter. First, some minor corrections, amendments, etc.

Please spell my name as my mother did: AMROM H. KATZ.

Page 2, conclusions, paragraph II B. Do you mean by "fusion", an operation employing both types in complementary roles? "Fusion" implies marriage in the same bird. What do you mean by "communication capability" in this context? We're not clear on this.

Naming 117-L a surveillance system doesn't make it so. Surveillance, timeliness requirements, purposes--as were presented to us are weak. A real study of surveillance and its implications for satellite design has not been made.

Page 2, paragraph III A2: For this section, I suggest substitution of the following:

"It should be clearly recognized and stated that there is role for reconnaissance satellites which talk back as well as those from which data is recovered physically. The overriding characteristic of systems from which data is recovered physically is that they can collect much more data faster than can

SECRET

talk-back satellites. Advantage should be taken of this characteristic, and detailed plans for use of large cameras in various size satellites should be formulated."

Under paragraph III B, top of page 3, add the following:

In the opinion of the committee, accurate mapping should be done from a high-altitude wide angle camera system using a between-lens shutter, with camera stabilized to the vertical, and with physical recovery of the film. Such a system will be far superior to the 117-L camera system.

For paragraph III C1, page 3, we suggest better clarity will be achieved with the following wording.

A ferret system should be flown as soon as possible. If a launching is available prior to readiness of F2 then F1 should be flown. However, if F2 is ready by the first available launching then F2 should be flown instead of F1.

In paragraph III C-3, page 3, the word "probe" is unnecessary. We don't use it elsewhere, and it tends to make the COMINT effort look too different from the other efforts. Besides "probe", in its best usage, refers to a non-orbiting high altitude shot, as in "upper-atmosphere probe", etc.

In paragraph III-D-3, page 3, I suggest some expansion and clarification as follows:

Problems of photogrammetry, whether they be locational, distance, azimuth, or size measurement, require more emphasis and attention in sub-system I. The possibilities of, and problems in doing weather-data reduction within SSI, whether they be for other users, or as an internal aid in conducting 117-L operations, require both attention and emphasis. The possibility of furnishing data and displays useful for more than one P. I. at a time also requires further attention and more extensive emphasis.

We next come to a discussion of paragraph III D5, and also paragraph 4 of page 10- on computers.

As you will note, I have no substitute statement, just some considered thoughts which you may use, abuse, or disregard.

An essential point would be recognition of the significance of the functional spec. mentioned here. On the other hand this is the consequence of a whole data system philosophy and design which must be examined with great care in order to appreciate it or differ with it--and we haven't done this. On the other hand you can bet that the spec. as presently framed automatically excludes all commercially available machines. It may be meaningless to solicit bids on such a spec., and the committee cannot dicker with the spec. until the committee comprehends and passes judgement on the whole system design.

Further, much as we are intrigued by this computer matter, some of us question

the utility of raising the question this late.

It seems unlikely that we could get a well-written spec., get it criticized, approved and bid upon in much less than six months.

Similarly, the expression in III D-6, page 3 seems oversimplified. What we really would want, instead of a "census of questions and problems" from R-W is a well-reasoned discussion of data-handling concepts which they find necessary, a discussion of tasks, including statements of who should do what tasks, where, how fast, with what new data, and with what filed data. I assume your use of "census" embraces all this, but others reading the report might think we're even more naive than we ourselves believe we are.

By and large, your section IV, page 3 is O.K. We would suggest adding a comment that we are opposed to inserting a 24" camera development into the series, especially when grounds are limited. Further, at the present state of art the electrostatic storage system does not appear to warrant the preference ARPA gives it. Also, the notion of modular design in sensors and vehicle, which ARPA stresses, can only increase costs at this time, and add further delays to the program.

Paragraph IV-I should be changed to read, "ground data receiving stations", to avoid confusion with the data handling and reduction center.

Now for some more details on the expansion of the first few pages of the draft report. What I want to and would have to say about the use of "strategic warning" would take more space and more time than is available. Briefly, the repeated use of the phrase tends to lend credibility and plausibility to our ability to accomplish strategic warning. It ain't necessarily so.

We should replace this phrase with a paragraph, defining carefully what's meant, delineating carefully the difference between "doing" strategic warning and doing those things which might contribute a piece to a probabilistic solution of the problem. Thus "doing strategic warning" is quite different from doing mapping, targeting, and the like. When we "do" the latter jobs, they're done, packaged, delivered, filed, etc. You should get the sense of my uneasiness and worry, so enough of this for now.

Further, some note should be made in the report of the observation by the committee that priority one problems may be glamorous and important, but what about priority two? No work on these till all of number one is done? What if number one problems stand around unsolved? Do we do nothing about number two? Personally, I'll trade a bagfull of insoluble number ones for a couple of good soluble number two priority problems. So warning is number one, so what? Some slight incorporation of these ideas into the report would please me greatly.

Now we come to section II, page 4, and we start with a small change: In the first sentence, change "from" to "for".

I think we can and should clarify the first paragraph of this section. It's not bad, but we can do better.

It occurs to us that "durability" is not the word to associate with data that is recovered physically. The real parameters to compare and evaluate the two kinds of data delivery systems are: timeliness, quantity, quality, geometric fidelity--among others. Consider for example, a recovery system which delivers in one day an amount of data at a given quality level which might take a month to telemeter back. Now clearly, with the talk-back system we might get some data earlier, but pretty soon the initial time-delay (a necessary evil) of the physical-recovery system is overcome, and the latter is delivering data faster than is the talk-back system.

Apart from this consideration, we might indeed get higher quality through recovery. Certainly mapping (discussed fuller later) requires geometric fidelity, and here recovery gets the nod without considerations of urgency or durability. For these, and other reasons, it is far from obvious that the two types of data will become undistinguishable, as you suggest on page 5.

You might add to the discussion on history (page 5, paragraph 3) a reference to lecture 26 of RAND's S-72, "A Course in Astronautics" for detailed exposition of this point.

Now to section III, page 6.

I think we can improve clarity in the paragraph starting, "As stated . . ." by changing "on research in the areas of reduction of data processing," to read "on research in methods of reducing film processing time so as to decrease current time delays built into the present system".

I think this is enough of a summary, so nothing needs filling in on page 6.

Page 7 needs a section B. Here it is:

Section B, page 7

I suggest that the following is what is needed for committee comments on mapping:

It is abundantly clear that we are entering an era in which there will be reconnaissance satellites of various types for various purposes, and operating with different data sensors at assorted altitudes and other orbital parameters, for different lifetimes, and with different ways of returning data to earth. Therefore it should no longer be necessary to maintain that all reconnaissance tasks that need doing from satellites can be done best from those configurations now planned under 117-L programs.

Mapping is the example we will now consider. This committee has been discussing the mapping problem in the satellite context since the Spring of 1958.

Based on some work then in progress at RAND and reported on to the committee it seemed reasonable to describe and summarize the essential features of 'mapping' satellites as compared with 'reconnaissance' satellites in the following table.

	Mapping	Intelligence
Camera type	distortionless, wide angle, between lens shutter, square format only	hard format, strip camera, panoramic, focal plane shutter or between lens (camera type not important)
Required Stabilization type	Horizon stabilization required, camera axis pointed vertical	Horizon stabilized or spin stabilization O.K.
Operational Life-time	Short life O.K. (e.g., 1-3 days)	For surveillance, long life times may be needed (e.g. 1 month)
Data return method	Physical recovery of film needed	Video talk-back or physical recovery O.K.

It is understood by the committee that RAND RM-2179, "Notes on Potential Military Space Systems", dated May 23, 1958, (pp 67-86), prepared especially for AFDRQ, contained a discussion of the satellite mapping problem. It is also understood that GOR 80-4 was based on this material.

Note: The rest of this section is adapted from some material prepared for the final report of the House Select Committee on Astronautics, released on January 9, 1958.

One problem which has not yet received sufficient attention is that of producing accurate maps from satellites. It is now possible to sketch out briefly the nature and components likely to be required in a mapping satellite. The problem of mapping is radically different from most other kinds of reconnaissance problems. In particular, mapping is concerned with geometric fidelity: the relationships between points. 'Intelligence' photography is concerned with detail at a point.

Ground resolution, however calculated, is an over-conservative statistic of the performance of a mapping system. As a suggested insight into the nature of the problems and solutions, we may consider the following. For a photographic system designed to map the earth accurately with geometric accuracy, 'hard photography' is a must. While in principle, the distortions arising from use of focal plane shutters and panoramic or strip cameras may be 'handled' by very clever analysis systems on the ground, there is no question that this is doing it the hard way. The kind of solutions which map-makers have always required is to secure wide-angle photography with a highly corrected, essentially distortionless lens, the entire photography being taken simultaneously (that is, with a between-lens shutter) instead of sequentially as with

focal plane shutters, strip photography, and panoramic photography. Extremely good wide-angle optical designs are now available. Distortionless optics capable of at least 50 lines/mm over the entire field have been developed by USAF and are available. On the assumption that we are after geometric intelligence instead of intelligence data as customarily defined and procured, the calculation of ground resolution for the case of a 6-in. mapping lens at 4000 miles altitude and 50 lines/mm yields a ground resolution of about 2500 ft. (These numbers are not necessarily recommended numbers for either focal length or distance, but are likely the shortest focal length and greatest distance which we would ever consider for this application.) Now, 2500-ft ground resolution might indicate to the lay observer that this might be somehow the limit of our measuring ability for distance between two points. This is not true. It is well known to astronomers that distances between two blur circles can be measured to a small percentage - that of the blur circle. If the best modern practice is used - that is, techniques employed by careful workers in astronomy - it may be assumed that a distance may be measured, or the distance between two points may be measured, on a photographic plate to perhaps better than 10 times the threshold which would be indicated by the resolution calculations made above. For this extreme case - 4000 miles and a 6-in. lens - this would indicate the possibility of achieving 250 ft.

There are many other problems associated with mapping. In particular the use of film instead of glass plates (as would be necessary in satellites) imposes the requirement for the emplacing of careful registration marks in the form of a reseau or fine grid on the plate, carefully calculated; fiducial marks along the edges of the format are also necessary. It is felt that techniques such as these, employed with care and thought (thought preferably applied in advance of the operation), can yield precision measures. Measurements to 2 sec or arc seem therefore within the state-of-the-art. Measurements of 2 sec of arc correspond to the precision which we think can be achieved by careful handling. These numbers can be used to go up and down the scales of altitudes and focal length. For example, coming into an altitude of 1000 miles with a 6-in. lens gives numbers 4 times better than those given above. Coming in to 1000 miles with a 12-in. lens (not unreasonable for a mapping satellite), gives numbers 2 times better than these, or 8 times better than the numbers calculated for the 4000-miles - 6-inch combination. Thus, in principle, we could measure to perhaps 30 ft. The speed in orbit of a satellite at 300 miles altitude is about 25,000 ft/second. An exposure time of 1/500 second implies a maximum blue corresponding to 50' on the ground. At much greater altitude, the orbital speed is even less. This amount of blur could be ignored, or alternatively, a very simply and fixed amount image motion compensation can be applied to the film during the exposure to remove this blur.

The flat-earth approximation would yield a ground coverage for the conventional mapping angle of 76 deg. fore and aft, or one and one-half times the altitude; since the earth is curved, the coverage is in excess of this. It would not take very many pictures from altitudes of 1000 or more miles to map the earth successfully. To recapitulate: a 12-in. lens at 1000 miles

yielding 50 lines/mm would give a ground resolution of about 300 ft. with a measuring ability perhaps 10 per cent of that, or say 30 ft. The precision of these numbers is not critical. What is important is to recognize that we can measure distances with accuracy greater, in principle, than that specified by the resolution limit as calculated above. What is also important is to realize that excellent modern wide-angle optics are indeed available. Now let us look at the characteristics of such a system.

A mapping satellite will require a stable table, that is, a platform stabilized with respect to the horizons. It will require recovery of film. It is mandatory to return a precision photograph directly for examination rather than to incur possible geometric degradation via electronic relay station. This would probably require auxiliary ground tracking stations, and perhaps visual beacons aboard, to locate the satellite precisely. It might require simultaneous star photography for precision determination of the satellite attitude at moments of exposure.

For mapping, we will want as few photographs as possible, hence the emphasis above on extreme altitudes. At 1000 miles, each photograph would cover at least 1500 X 1500 miles. Only a few photographs would tie the S.U. to existing control nets. The fewer photographs required to tie together, the 'harder' the tie. It is crucial in these considerations to distinguish between the following two situations.

First, a map-maker may be asked if he is willing to try to use the programmed product of 117-L. In the absence of anything better, of course he will want to use the product.

Second, a map-maker may be asked which he'd rather use: hard, distortionless, wide angle photographs or a video-play back of a sequentially scanned film. Under these circumstances, there is no doubt as to his choice. He would want and insist on, the hard photography. It is worthy to note that on the one hand, the technical people who insist and attempt to demonstrate that mapping data of high accuracy can be obtained from the programmed 117-L product have never had anything to do with the intricacies, devilments, and subtleties of mapping, whereas the Aeronautical Chart and Information Center, the Army Map Service, the mapping groups at RADC and Aerial Reconnaissance Laboratory are in favor of a recoverable system with the characteristics described above.

In light of the open and revived interest in data recovery, and in view of an already existing and active interest in an office of BMD (other than the 117-L office) in exactly such a mapping satellite configuration as the committee feels is needed, it is clear that 117-L should face the facts and reorient its program accordingly.

Back to page 6--remarks on the 36" camera-change "in a single pass" to "in a single day". We should strengthen the remarks on stabilization by saying "whether this is achieved by means of spin-as in RAND's RM-2012, the Army proposals, the ARPA WX satellite, the Pioneer flights, the Air Forces Lunar probes or by some other method".

In C-2, page 7, we might logically anticipate that at some future time we might fly a ferret which makes wideband analog recording of intercepted signals. It is possible that we might then need to deliver more data than even a wideband telemeter link capacity can handle. (This argument should be added as proof of committee foresight, if such is still needed.)

Paragraph C-3, page 8, again associates "probe" and "COMINT". I'm in favor of excising "probe" and substituting "satellite".

The discussion of SS-I, paragraph D-1 page 8 is incomplete. You must work into this section the idea that these satellites are going to be gathering data at quality levels far above what USAF Recce Tech Squadrons are used to. Simply put, 100 lines/mm photography requires special gear-to print, enlarge, view, etc.

In paragraph C, page 8, there is no distinction between photogrammetric measurements, such as length of an airstrip (quick, and easy) and that kind of photogrammetry which is involved in targeting, mapping, etc. The latter won't fit in your one to twenty-four hour limits of paragraph a, page 9.

Now to section IV, Comments on ARPA letter.

Paragraph IV B, refers to the ARPA "all-electronic" system. Here ARPA meant electrostatic tape; clearly magnetic tape could fit in. The tape is only the recording medium.

Paragraph IV C, page 11, refers to the insidious notion of combined photo and ferret. In the first place, the photo gear would be dead-heading through space whenever it is dark or cloudy (which is most of the time) whereas our ferret gear couldn't care less about night, day, darkness, or clouds. This ARPA argument is some of the usual half-thought out jazz we hear on combined sensors. Another thought here: the limitation on payload life or power drain imposed by auxiliary power availability will be with us for quite a while.

It must be noted, in connection with the Thor-Atlas discussion of paragrph F, page 12, that we cannot simply take the payload being developed for Atlas and paste in onto a Thor. Use of Thor requires specially designed payloads.

Add to paragraph H, page 12, the strong notion that even for recovery satellites we need a SS I of some kind, perhaps with a center of gravity weighted toward viewers, enlargers, (and other gear that has to do with high resolution) instead of toward computers. Apparently ARPA doesn't know what the ground part of the reconnaissance cycle, how it works, etc.

A few misspellings in paragraph H, page 14, but I assume these are typos only. If you can't find them, call collect. Also, the band-width of the video channel is not the only limitation-all the rest of the pieces will need fixing-scanner, recorder, ground recorder, antennas.

Now a few more spellings: page 16, it is Amrom, T. Finley Burke, probably Winston Fromm, Dr. Stanley Kamemy, Mr. Stanley Rothman. Page 17, it is Col.

Dr. Harry Goode -2-

H. Macia. On page 18, continued use of the misspelling of Woodshole may give rise to an embarrassing but appropriate Freudian slip, so change it to Woods Hole. Page 21, paragraph II - Win is his nickname. I think it should be Winston. Page 21, paragraph B1 - location is not stored - but must be computed on the ground from orbital data. Page 23, line 7, Miles is not unapproved, just unproved. Same page, correct Enemy.

Now, when I come to the question of early warning, Garland's remarks, Loftus' points, I realize that either you clip some of my remarks from the previous letter and insert them, or wait for another meeting.

This letter has gotten too damn long, so we will leave some unfinished business.

Sincerely,

Aaron H. Katz
Electronics Department